NAVIGATING DILEMMAS OF STUDYING MATHEMATICS ENGAGEMENT IN SECONDARY CLASSROOMS

Amanda Jansen
University of Delaware
jansen@udel.edu

Adi Wiezel
Arizona State University
adi.wiezel@asu.edu

Xiaoxue Zhang
University of Delaware
veraz@udel.edu

Kelly Curtis
University of Delaware
kbcurtis@udel.edu

James Middleton
Arizona State University
jimbo@asu.edu

To better understand how to support high school students' engagement, advancements in research methods that provide greater understandings of malleable factors of engagement and conditions that affect students' engagement are needed. In this conceptual paper, we introduce four dilemmas that researchers need to navigate to study secondary students' engagement with mathematics: How can we concurrently capture engagement in-the-moment and at scale? What counts as a moment or experience? What sorts of experiences could be engaging? Whose perspectives on the experience should be privileged? We propose approaches for navigating these dilemmas in the context of a current research project.

Keywords: Research Methods; Affect, Emotions, Beliefs, and Attitudes; High School Education

The decline of students' motivation and engagement in mathematics as they move through levels of education is a persistent problem. Students' self-efficacy, their enjoyment, and their sense of the utility of mathematics tends to decrease as they move from elementary school into junior high and this trend continues through high school (Chouinard & Roy, 2008; Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991). To develop insights about how to create learning environments that engage more students, more deeply, researchers must develop approaches that allow for a greater understanding of students' engagement.

Historically, research on engagement and its associated constructs has been conducted either at a small, descriptive scale, *or* at a larger, probabilistic scale. This issue of scale ranges on two dimensions: idiographic → nomothetic and momentary → longitudinal. Ideally, learning environments would be designed to promote positive experiences at all levels. From the learner's perspective, which is primarily idiographic and momentary, we want to find ways to "catch and hold" their engagement. From the perspective of the education system, which is primarily nomothetic and longitudinal, we want to increase the chance that learners will identify with mathematics-related disciplines and choose to continue learning mathematics far into the future. In particular, greater insights are needed about how to foster engagement with mathematics among high school students. Prior research suggests that instructional practices such as teachers' demonstrations of warmth and focus on understanding over performance engage students (Stipek, Salmon, Givvin, Kazemi, Saxe, & MacGyvers, 1998), but this research was conducted in classrooms with elementary school students. Alternative approaches that address nuanced differences, are likely needed to engage high school students; they are in a different developmental stage both cognitively and socially, and are learning more abstract or otherwise different mathematics. What *is* known is that high school students are more engaged with mathematics when they experience authentic work such as being asked interesting questions, solving novel problems, digging deeply into understanding a single topic, applying the subject to problems and situations in life outside of school, and discussing ideas about the subject with the

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teacher or students, along with pedagogical strategies that support students socially (Marks, 2000). However, what counts as authentic (i.e., *interesting, novel, applicable*) for some students may not be so for others, and means of social support have numerous facets that are worth understanding more deeply in high schools.

The purpose of this paper is to provide a critical analysis of concepts and methods for studying engagement with mathematics in the moment in high school classrooms. We propose an approach, which we are currently undertaking, that goes beyond fine-grained analyses of a few students to seek out larger trends in a manner that is still situated in the context of classroom opportunities to engage in mathematics. This approach also delineates variability within and between classrooms that might explain some of the reasons students both turn on and turn off from mathematics during the high school years. Below, we describe our approach to investigating students' engagement in relation to four dilemmas, but before we do so, we share our orientation on engagement.

What Is Engagement?

Previous work has considered engagement as both an anthropological and a psychological construct. Anthropologically, engagement can be understood as students' opportunities to participate in a particular activity. Psychologically, engagement is often conceptualized as a personal endeavor, emphasizing how psychologically present a person is during a moment in which they are actively involved (including, but not limited to, a pedagogically relevant experience in a math class) (e.g., Shernoff, Csikszentmihalyi, Schneider, & Steele, & Shernoff, 2003). Engagement can also combine the two approaches, emphasizing sustained behavioral involvement (i.e., making use of opportunities to engage) combined with some emotional tone, either positive or negative, in context. By this view, all students are engaged in some fashion and to some degree, though not all engagement is positive. For example, when engagement occurs by the demands of the educator rather than the will of the student, it may instead manifest as anti-engagement, sometimes termed as *disaffection* (e.g., Skinner & Belmont, 1993).

A useful conceptualization of engagement in mathematics classrooms is a person's investment in a pedagogically relevant object of engagement, such a mathematics task or lesson, as situated in the relationship between the self, the object of engagement, and others in the environment (Middleton, Jansen, & Goldin, 2017). Engagement is dynamic and multi-dimensional. It manifests itself in affect, cognition, behavior (Fredricks, Blumenfeld, & Paris, 2004), and under some definitions, social interactions (e.g., Rimm-Kaufman, Baroody, Larsen Curby, & Abry, 2015; Wang, Fredricks, Ye, Hofkens & Lin, 2016).

Although these four components of engagement (affective, cognitive, behavioral, and social) interact dynamically, they are often defined separately. For instance, the affective dimension of engagement involves both more immediate positive and negative affective reactions to stimuli such as math activities, teachers, or classmates, (Fredricks, Blumenfeld, & Paris, 2004), and higher-order evaluation of those reactions (e.g., Goldin, 2002; Goldin, 2014); for example, perceiving the struggle involved in solving a math problem as enjoyable. By contrast, the cognitive dimension of engagement involves effortful cognitive coordination between prior knowledge and current information (Middleton, Jansen, & Goldin, 2017). Exemplars of cognitive engagement include concentration, and memorization. The behavioral dimension of engagement, then, includes the positive *behaviors* associated with a student's productivity in the math classroom (Rimm-Kaufman, Baroody, Larsen Curby, & Abry, 2015). This entails the actions students employ working on math problems and collaborating with peers. Finally, the social dimension of engagement relates to the quality and investment in social relationships and

nature of interactions, such as those with peers and teachers (Wang, Fredricks, Ye, Hofkens & Lin, 2016). We now turn to a critical analysis of four essential dilemmas researchers must face when studying engagement from this perspective.

Dilemma 1: How Can We Concurrently Capture Engagement In The Moment And At Scale?

Engagement is highly dynamic, particularly on a moment-by-moment basis. An uplifting mood, a novel mathematics problem, and an open and welcoming classroom environment might each increase engagement in the moment. However, over time, these dynamics may become less extreme as they become habituated (e.g., a mathematics problem becomes less novel the longer one works on it). It is important, therefore, to consider whether the goal is to capture students' *tendencies to engage* (which may stabilize over time) or to understand conditions that impact the more *malleable* aspects of students' engagement to foster change in engagement patterns. When researchers investigate students' tendencies to engage, they learn about variations between individual students, understanding how different students experience mathematics learning. Alternatively, when researching engagement in the moment, researchers can understand factors that can impact why and how engagement becomes more and less productive for different people at different times. Moreover, sometimes researchers are interested in both the stable and malleable aspects of engagement, trying to piece out what aspects are productive, and what features of classroom practice support productive engagement patterns.

Different pursuits require somewhat different methodological approaches. Researchers interested in students' more stable tendencies to engage have relied on the use of long-term surveys and proxies for successful outcomes, such as grades (Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). In contrast, research on engagement in the moment has relied on qualitative data collection techniques such as observations (focused on individuals, small groups, or classrooms), videos, and observer field notes followed up by interviews involving video viewing sessions (e.g., Esmonde, 2009; Gresalfi, Martin, Hand, & Greeno, 2009; Webel, 2013) to capture students' rich experiences in the moment. Although work in this qualitative tradition has contributed considerably to knowledge about student engagement, the intensive nature of such qualitative data collection has typically necessitated the use of small samples, which does not enable seeking wider trends. Efforts to understand students' experiences in the moment have been scaled up using the Experience-Sampling Method (ESM) (e.g. Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003), in which respondents are signaled at random intervals or around pre-determined experiences, and complete a series of (closed-ended and/or open-ended) questions about their experience in the moment (Shernoff, 2013). This method has the added benefit of capturing students' impressions in real time relative to later retrospective measures (such as after-the fact interviews) (Shiffman, Stone, & Hufford, 2008). Researchers interested in both the stable and malleable, in-the-moment, aspects of student engagement benefit from triangulating methods. For example, we are currently combining methods ideal for measuring changes in stable traits, such as longer-term surveys, with more in-the-moment methods, such as ESMs, interviews, and observation, as in Figure 1. In Figure 1, our data collection begins with the administration of a long-term survey assessing students' more stable perceptions and traits. This initial survey serves two purposes. First, it can be used to establish a baseline measurement of initial perceptions. These baseline measurements are then repeated at critical times, most notably at the end of data collection, with a post-test version to examine change over time. This provides a check on the validity of the processes going on between the two points of study as well as a means of assessing the effect size of the impact of

the processes occurring between long-term survey measurements. Second, responses to the long-term survey can be analyzed using cluster analysis to select focal students to follow up with using qualitative methods, such as observation and interviews (e.g., Patrick & Middleton, 2002).

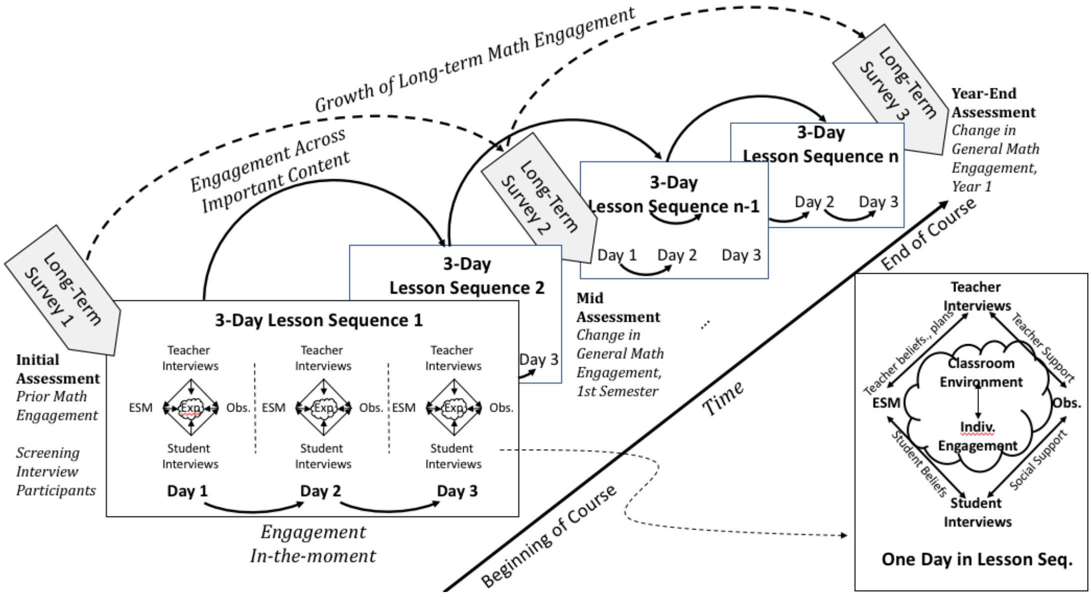

Figure 1. Mixed methods model for studying student engagement over time in one classroom.

Note: In our current project, some classes use a block schedule, completing a course in one semester. Others follow the traditional year-long course model. The number of lesson sequences and long-term survey administrations vary accordingly, with fewer administrations in the block scheduled model.

Data collection then focuses in on a series of pedagogically relevant experiences during a given class period, often identified in advance by the teacher and researcher (a dilemma described further below). During each of these experiences, a series of measurements—ESM surveys, observation, student interviews, and teacher interviews—are taken in parallel in a convergent design (e.g., Creswell & Clark, 2018), characterizing the student's engagement in all of its nuances. By this view, engagement in the moment in Ms. Smith's freshman algebra class is determined by triangulating the teacher's thoughts on the observed session with researcher observations and videos of each experience, with students' in-the-moment ESM reports of their affect and behavior, and finally, with retrospective interviews asking the students about their impressions of each experience. Each of these data points measures and helps describe a given experience and students' engagement in it. Over time, this can uncover the potential factors of classroom practice that *cause* change in engagement, or that *support* engaged behavior over a relatively long period of time, such as a course or academic year. Such mixed methods can characterize the moments of mathematics engagement, provide an explanatory narrative of their development, and estimate their effect size.

Dilemma 2: What Counts As A Moment Or Experience?

When investigating students' engagement, grain size matters. Doing mathematics in school can be viewed as a set of experiences strung together by time, topic, practices, and roles. Thus, an experience could be an entire school year or semester, a single class period, an activity during a class period, or a mathematics problem within an activity. Many studies at a larger scale focus on the longer-term, such as a course, semester, or year (e.g., Skinner & Belmont, 1993). Smaller

scale studies focus on the class period, activity, or task-level (e.g., Gresalfi, 2009). The more fine-grained the timescale, the more detailed insights can be gained about engagement. But to understand how to impact students' engagement, whether long-term or short-term, researchers must record the conditions giving rise to engagement patterns, the engagement patterns themselves, and finally, the ways in which students conceptualize their engagement and use it to direct future mathematics-related activity.

By experience, then, we mean an interactive situation (with mathematics content and with others in the classroom) structured by some mathematical task, *cued* by the teacher or students. A *cue* is a social act proffered by a person that indicates an *intended shift in the group interactive behavior* in the mathematics task. Experiences could be operationalized in the context of a teacher cueing, such as launching or introducing a task with various forms of participation, such as having students work on a task (in groups or alone), or discuss a task in small groups, with partners, or as a whole class. Experiences can could also be cued by a student's query about a mathematics concept or procedure.

Yet, this raises another question: is the experience bounded by an activity or by a mathematics problem? We could consider students' engagement during an entire activity, such as the timeframe when students are working together in a small group, as an "experience." Alternatively, we could monitor students' engagement problem-by-problem when working in small groups, considering each problem to be an "experience" in itself.

Ultimately, our definition of experience fundamentally shapes our research methods. For instance, we can take a problem-centered approach by using an ESM to ask participating students to reflect upon the same experience at the same grain size. We can ask for such input either at the end of a given problem, or an entire group task—reflecting either a problem-centric or more holistic approach to the "experience." Such methods could support comparison of students' perceptions across particular experiences, as well as researchers' attempts to track the coincidence of behaviors and reported feelings across particular experiences.

We can also have students or teachers participate in a video viewing session to reflect back on students' engagement, using criteria to select a particular moment in the video record to reflect upon that participants will recognize as an experience, with some beginning, end, and flow of activity. The selection of a clip for a video viewing session can be based on a range of criteria. A focal experience could be one that the teacher conjectured would be productive for students' learning and engagement. Alternatively, researchers could choose a moment that they conjecture could be engaging (or not) for students based on students' displayed affect, and ask the teacher and students to reflect back on that moment.

Each of these potential selection criteria reveal different information regarding what the engagement patterns of the experience are, and what the causal impact of teacher behaviors, mathematics curriculum, and the social setting might be. Defining criteria for selection of experiences that matter, then, must be done carefully, with clear theoretical guidance to generate coherent epistemological claims.

Dilemma 3: What Sorts of Experiences are Engaging?

Following Shernoff et al. (2016), we conjecture that engaging experiences are situated in a learning environment that includes both academic and social support. It is worth investigating the degree to which mathematics learning environments provide students with (a) opportunities to engage in sense-making and reasoning and (b) opportunities to experience positive social interactions. Figure 2 presents hypotheses of classrooms that are likely to result in very different patterns of engagement among students.

A. High sense-making & reasoning Negative social interactions	B. High sense-making & reasoning Positive social interactions
C. Low sense-making & reasoning Negative social interactions	D. Low sense-making & reasoning Positive social interactions

Figure 2. Four patterns of academic and social support

One hypothesis is that when classrooms provide students with academic support through opportunities to engage in sense-making and reasoning (as in A. and B. in Figure 2), students will be more engaged with learning mathematics. For example, prior work has suggested that learning environments that promote making sense of challenging mathematics and opportunities to reason mathematically engage learners in developing mathematical understandings, and, in turn, raise students' self-efficacy, interest, and mastery goals (Stipek et al, 1998).

Another hypothesis is that when classrooms provide students with social support through relatedness (as in B. and D. in Figure 2), students will be more engaged with learning mathematics. Learning environments that are warm and welcoming such that they promote positive social relationships between the teacher and students, and among the students, allow students to feel safe to take intellectual risks and to develop positive emotional well-being (Stipek et al, 1998). Students will then exert more effort spent toward learning mathematics.

Realistically, most classrooms fall in the in-between space of academic and social support, such that sense making is pretty good at some times for some students, and pretty poor at others times for others. Social support may vary likewise at some times and for some students. This makes investigating the dynamics of the pedagogical and social situating of mathematics classrooms so critical for the study of engagement.

To investigate the degree to which such learning environments are engaging, a number of questions could be pursued, such as: How prevalent are learning environments that are high in sense-making and reasoning in these schools; how prevalent are learning environments that focus on positive social interactions in these schools; and how does this relate to engagement? Although learning environments that are high in sense-making and reasoning as well as positive interactions should lead to greater engagement, and learning environments that are low in sense-making & reasoning and have negative social interactions should lead to lower engagement, what does students' motivation and engagement look like in learning environments that are high in sense-making & reasoning and negative in social interaction OR in learning environments that are low in sense-making and reasoning and positive in social interaction?

Dilemma 4: Whose Perspective On The Experience Should Be Privileged?

Multiple perspectives on a school mathematics experience are likely to provide broader insights not only about how or why an experience is engaging, *but for whom*. Nevertheless, consulting different viewpoints also offers the opportunity for discord. When different viewpoints depict differing accounts of who is engaged in the classroom, whose account should be given precedence: our own observations as researchers or students' self-reports?

One answer is to focus on students' own perspectives (in contrast to researchers' perspectives). This seems defensible; even though engagement has dynamic components and is influenced by classmates and teachers in the classroom, engagement is fundamentally a personal, psychological phenomenon. However, the different levels of analysis we prioritize (whole class,

a small group, individual student, interactions between these), have implications for the content of interview questions and on the conclusions we are able to draw. For example, in his high school case study of goal development, Webel (2013) found that although engagement behaviors were relatively stable at the group level, they varied considerably at the individual level. Each student's goal-seeking behaviors were expressed differently based on the extent to which they perceived a match between their own goals and that of the group. Had perceived goal match not been a measure in Webel's work, this relationship would have been obfuscated. This suggests a need to capture a broad array of student perceptions, both at the group and individual levels.

Another dilemma that comes with prioritizing students' impressions of engagement is which temporal student account to prioritize. In the mixed methods approach we advocate above, for example, researchers can choose to prioritize in-the-moment assessments, such as the ESM, or retrospective reports, such as student interviews. Each of these methods have been used in meaningful ways across different studies. For example, research using ESMs has suggested that high school students experience more concentration, but less interest and enjoyment when they are in class compared to other places (Shernoff 2013), while research using semi-structured interviews has suggested that seventh-grade students' beliefs about participation (e.g., beliefs constraining or supporting it) influenced the goals they had during participation (e.g., to help classmates and behave appropriately, or to demonstrate competence and complete tasks, respectively) (Jansen, 2006).

Moreover, within the context of a single study, it is possible that a student's in-the-moment impression of an experience may be different than her after-the-fact account. A quiz that seemed difficult in the moment may seem easy retrospectively once the student learns that she had earned an A. What then? Prior research from other domains has suggested that in some cases, willingness to re-engage in an activity (such as an invasive medical procedure) is better predicted by a person's after-the fact impressions than in-the-moment impressions (Shiffman, Stone, & Hufford, 2008). Such discoveries require the measurement of both in-the-moment and later impressions to determine how such memories are consolidated. This suggests yet another utility of using mixed methods, as well as interesting possibilities that may arise from comparing the results of different measurements on educational and persistence-related outcomes of interest, such as grades, and desire to continue in math or pursue a STEM career.

Conclusions

Through this essay, we explored a range of considerations for researchers who are interested in the study of secondary students' engagement in school mathematics classrooms. We reflect upon a current project that attempts to address these considerations. A premise guiding this work is that students' voices should be solicited through multiple methods: long-term surveys of tendencies, ESM surveys, and interviews. We urge for the study of engagement to go beyond observational methods so that students can share the degree to which they experienced the observed incident as engaging. The dilemmas we explore support research that examines engagement in the moment but in ways that also explore trends over time and allows for uncovering variations within individual students as well as between them.

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